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New energy bases and sustainable development in China: A review

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ABSTRACT

Due to the rapid economic and social development, China's power generation mix is dominated by thermal power, resulting in rapid growth of CO_2 emission during the past decades. Suffering from the two severe problems of energy crisis and global warming, power generation mix should be optimized by installing more new energy during China's 12th and 13th Five-Year Plan periods. In order to realize the massive utilization of new energy and realize emission reduction targets in the future, it is of great significance for China to promote development of large new energy bases such as hydropower, wind power, solar power, nuclear power etc. In this paper we provide an overall review of China's large new energy bases development with a detailed presentation of construction status and future plan, analyze the policy problems and technology barriers hindering the development of new energy bases in China, which will provide sound reference for policy makers.

Contents

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1. Introduction

Coal is the primary energy resource in China, which provides more than 70% electricity generation during the past decades [1]. However, serious environmental negatives such as health problem to inhabitants, ground sedimentation, land degradation and water contamination are caused, further accompanied with the increasing emission of CO_2 which contributes the most to global warming [2,3]. Under the dual pressures of international carbon reduction and the sustainable development of domestic energy in China, the goals of clean energy development and low-carbon economy growth are proposed in the 12th five-year plan [4], focusing on the development of hydropower, wind power, solar power, nuclear power and other new energy resources. New energy resources are abundant and with salient feature of regional distribution in China. In order to improve the generation mix and make good use of new energy resources, it is of great significance for China to promote the development of large new energy bases according to natural resource endowments [5,6]. According to China's 12th five-year plan, non-fossil fuel generation should account for 11.4% and 20% of the total primary energy consumption by 2015 and 2020 respectively [7]. This paper focuses on the sustainable development and future plan for hydropower bases, wind power bases, solar power bases, nuclear power bases and other new energy bases in China; also policy recommendations would be provided for policy makers.

2. New energy resources in China

During the 11th five-year plan period, the rapid development of China's power industry had basically met the needs of national economic and social development, but disorganized growth of power industry caused severe environment pollution. By the end of 2011, the installed capacity of thermal power, hydropower, nuclear power, wind power is respectively 72.5%, 21.8%, 1.19% and 4.27% in China as shown in Fig. 1(a) and the electricity production is respectively 82.54%, 14.03%, 1.88% and 1.54%.

In recent years, China has made a significant progress in the exploitation and use of new energy resources. The exploited renewable energy in China is shown in Table 1. During the year 2011, 371.2 billion RMB has been invested for national power engineering construction, 71.61% of which is for non-fossil fuel generation investment [11]. The installed capacity of China exceeded that of EU by the end of 2011, but the proportion of non-fossil energy sources installed capacity in China is 44.86% lower as shown in Fig. 1(a). As for the newly installed capacity in 2011, non-fossil energy sources take up for 34.89% in China and make great progress, but it is still 37.15% lower than that of EU, as shown in Fig. 1(b).

In 2011, the generation installed capacity of non-fossil energy in China is 27.5%. There is a great difference in sharing of non-fossil energy sources in China and EU. The non-fossil energy in EU appears with the coexistence of a variety of energy, but China's distribution of non-fossil energy is mainly hydropower accounting for 80.36% of non-fossil energy production [12]. Despite the significant progress of wind power and nuclear power, China still lags far behind EU in solar power. Considering the rapid growth of power demand for a long time in the future and pressure from sustainable development of fossil energy, it is of great significance for China to adjust generation mix, make full use of non-fossil energy and promote the coordinated development of hydropower, wind power, solar power, nuclear power and other new energy resources.

3. Development plan for new energy bases in China

According to energy mix analysis, hydropower would play the most important role in new energy development and contribute considerably to emission reduction in the future. As for nuclear power, although the installed capacity is just 10 million kW by the end of 2010, its scale will increase largely in the future [15]. Due to intermittency and volatility, the installed capacity of wind power will be lower than hydro power and nuclear power by 2020. At the same time, the installed capacity of solar PV will not increase considerably before 2020 on account of technology and

Table 1
Exploitation of new energy resources in China [13,14].

Type		Exploited	Standard coal (Mtce)
Solar energy		1000 kW	17,000
Wind power		1 billion kW	2.46
Hydropower		4 billion kW	4.8–6.4
Biomass energy	Biomass power	0.6 billion t	3.5
	Biomass alcohol	50 million t	0.5
	Marsh gas	800 billion m^3	0.6
	Total		4.6
Geothermal		3.3 billion tce	33 (less suitable for power generation)

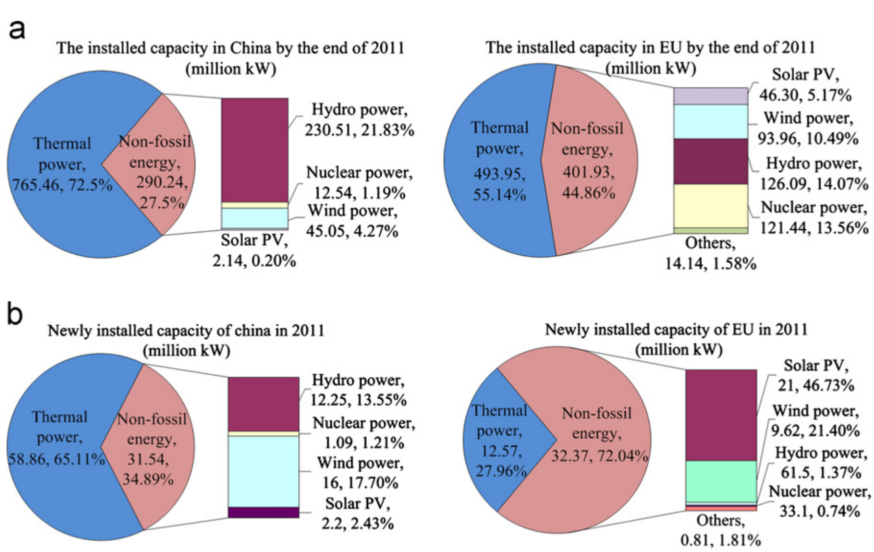

Fig. 1. (a) Installed capacity of China and European Union by the end of 2011 [8,9] and (b) newly installed capacity of China and EU in 2011 [8,10].

economics [16]. In accordance with the principles of security and economy, the National Grid Energy Research Institute (NGERI) has carried out scenario studies on the coordinated development of clean energy and power system during the 12th Five-Year period. Results showed that the total installed capacity may soar to 1.76 billion kW, with the installed capacity of coal power, gas-fired power, nuclear power, hydro power, pumped storage power, wind power, solar PV, and biomass power respectively reaching 1.03 billion kW, 58.9 million kW, 80.83 million kW, 340 million MW, 50 million kW, 150 million kW, 24 million kW and 15 million kW by 2020 [17], as shown in Fig. 2. With the increasing situation of total installed capacity, the installed capacity of new and renewable energy will reach 610 million kW in 2020, and its percentage increases from 26.54% in 2010 to 34% in 2020.

3.1. Hydropower

The exploitable capacity of China's hydropower resources is about 540 million kW, and 3886 mainland rivers have a capacity over 10,000 MW in theory. Hydropower generation would reach 6.0829 trillion kWh. According to the calculation of exploitable capacity on technology, so far the development and utilization rate is only 20% (data sources: China industry research institute). In 1979 and 1989, after two plans of the original electric power industry, the present 13 large hydropower bases have been formed as shown in Fig. 3.

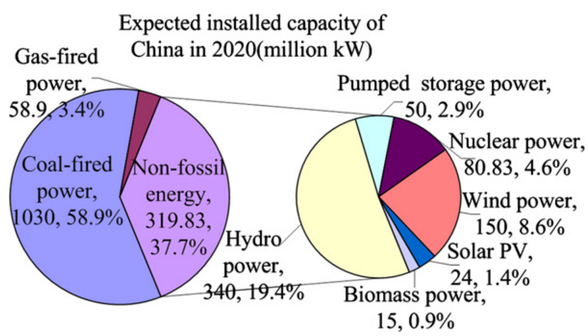

Fig. 2. Contrast of the installed capacity in 2020 [18,19].

The 11th five-year plan period is China's early development stage of large-scale hydropower, mainly located in the Northeast, the Yellow River and Yangtze River Basin. The newly installed capacity is planned to concentrate on hydropower bases such as the Yangtze River, the Yellow River, the Dadu River and the Lancang River. The development level of above 4 hydropower bases has reached 78.7%, 34.4%, 25.6% and 23.3% by the end of 2010, and the total development level of hydropower bases is about 25.3% as shown in Table 2.

During the 12th five-year plan and the 13th five-year plan period, China will accelerate the hydropower bases development in south-western areas with abundant hydropower resources [24]. Table 3 shows the exploitation of hydropower resources and installed capacity in southwestern provinces, including Yunnan, Sichuan, Tibet, Guizhou and Chongqing. During the 12th five-year plan period, China's hydropower installed capacity is expected to concentrate on hydropower bases such as Jinshajiang River, Yalongjiang River, Dadu River and Lancang River. It is estimated that development level of these four hydropower bases will increase to 29.0%, 57.3%, 68.7% and 57.4%, and the total exploitation level of hydropower bases is about 49.3% [22].

During the 13th five-year plan period, China's hydropower installed capacity is expected to concentrate on hydropower bases such as Jinshajiang River, Lancang River and Nujiang River, where the development level is relatively low now [23]. It is estimated that the development level of these 3 hydropower

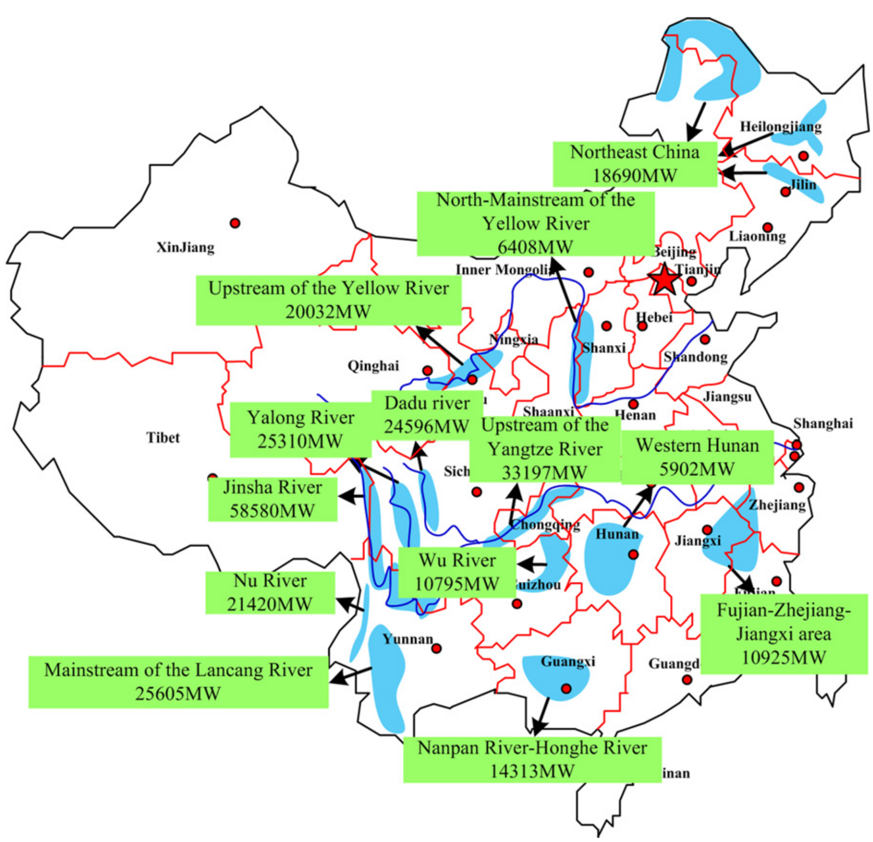

Fig. 3. Distribution of 13 hydropower bases in China [20,21].

Table 2
Development plan of 13 hydropower bases [22,23].

Hydropower bases	Hydroelectric potentiality	2010		2015		2020	
		Exploited	Development levels (%)	Exploited	Development levels (%)	Exploited	Development levels (%)
Jinshajiang River	5858	180	3.1	1700	29.0	3210	54.8
Yalongjiang River	2531	340	13.4	1450	57.3	1850	73.1
Daduhe River	2460	630	25.6	1690	68.7	2140	87.0
Wujiang River	1079	358	33.2	850	78.8	1010	93.6
Yangtze River up reaches	3320	2612	78.7	2750	82.8	2830	85.2
Nanpanjiang River and Hongshuihe River	1431	498	34.8	918	64.2	1192	83.3
Lancangjiang River	2560	597	23.3	1470	57.4	1960	76.6
Yellow River up reaches	2003	690	34.4	1250	62.4	1400	69.9
Yellow River main	641	163	25.4	343	53.5	579	90.3
West Hunan	590	176	29.8	310	52.5	519	88.0
Fujian and Zhejiang and Jiangxi	1092	330	30.2	567	51.9	845	77.4
the Northeast	1869	373	20.0	802	42.9	1131	60.5
Nujiang River	2142	18	0.8	300	14.0	720	33.6
Total	27576	6965	25.3	14400	49.3	19386	70.3

Table 3
Hydropower resource and installed capacity of hydropower in southwestern areas [24,25].

Province	Exploitable installed capacity		Exploitable generation		Installed capacity	
	Million kW	Proportion of total installed capacity (%)	Million kW/h	Proportion of total generation (%)	Million kW	Proportion of exploitation (%)
Yunnan	71	18.80	39	20.50	5	7.02
Guizhou	13	3.40	65	3.40	2.4	19.65
Sichuan	92	24.20	51	26.80	13	13.96
Tibet	57	15.00	33	17.10	0.29	0.52
Guangxi	14	3.70	64	3.30	4.2	29.92

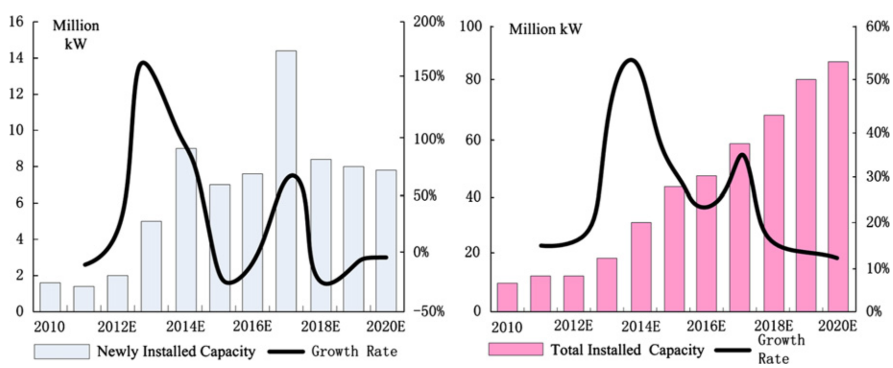

Fig. 4. Newly installed capacity and total installed capacity forecast of nuclear power [10,11].

bases will soar to 54.8%, 76.6% and 33.6% and the total development level of hydropower bases is about 70.3%. It is expected that the hydropower construction focus will gradually shift to Tibet and Xinjiang, and Tibet will be the latest hydropower base during the 14th and the 15th five-year plan period. Overall, large hydropower bases in China will mainly be constructed during the 12th and the 13th five-year plan periods. By 2020, the installed capacity of hydropower in Tibet will reach 2 million kW and its development level will increase to 1.5%.

3.2. Nuclear power

More than 200 uranium mines with total proved reserves of 4.4 million t have been found in southern China of the Qinling Mountains, Tianshan Mountains, Qilian, Yan Liao, western Yunnan and other regions, only accounting for 2% of the total world reserves. Therefore, most uranium fuel has to be imported to promote the development of domestic nuclear power. In 2008, 769 t uranium was produced in China, but it could not meet the nuclear power demand and 60% uranium had to be imported from Kazakhstan, Russia, Namibia and Australia [26].

To fulfill uranium needs for the installed capacity of 40 MW by 2020, China is projected to need 9814 t uranium by 2020. The cumulative demand is expected to be 89,992–91,364 t by 2020. Since 2000, China has planned to complete the aim of nuclear power with "40 GW installed capacity and 18 GW under construction by 2020" directed by the policy of "promoting the development of nuclear power actively". The medium and long term nuclear power development plan (2011–2020) improves the construction goal. On the basis of original planning of completing

the goal of 40 million kW installed capacity of nuclear power, the government should improve construction unit scale to slightly more than 20 million kW. In addition, nuclear power installed capacity will reach 58 million kW in-building and 30 million kW under construction in 2020 [27].

Future approved projects will still be located in the coastal zone, mainly the expansion of projects under construction. The capacity of AP1000 units for nuclear power is expected to account for about 30%, while the Generation II plus PWR NPPs units will still account for more than 50%. According to the long-term nuclear power development plan, China's nuclear power installed capacity will reach 86 million kW in 2020. According to the growth rate expected in the next decades, China will add 6.5 million kW annually, which is 2.5 times of 2.6 million kW in 2002–2007, ranking first in the world. Newly added nuclear power capacity in operation and the total installed capacity forecasted are as shown in Fig. 4 [19,24].

Choosing sites for nuclear power plants needs to satisfy nuclear safety requirements, fundamentally different from thermal power plants, including earthquakes, floods, soil, extreme weather conditions, aircraft crash, chemical explosion, and other external events such as natural environment, water environment, population density, human population distribution [4]. Fig. 5 shows proposed distribution of China's potential nuclear power plants.

3.3. Wind energy

As shown in Fig. 6, China's wind resources are mainly distributed in southeastern, northeastern, northern, southeastern coastal areas and inland areas, including "Sanbei Region" (Hebei, Qinghai, Inner Mongolia, Xinjiang and Hexi Corridor of Gansu Province). From macro perspective, China has relatively abundant wind resources. In these areas, wind power density is above 200–300 W/m^2, some even reaching 500 W/m^2 with the great wind development potential of 0.2 billion kW, accounting for 79% of the total available energy reserves. The coastline in China is about 1800 km with more than 6000 islands, wind power density there can even reach 500 W/m^2, and available hours range from 7000 h to 8000 h [28]. Fig. 6 shows the wind density map of China.

According to the Mid- and Long-Term Development Programming for Renewable Energy formulated by the National Development and Reform Commission, the cumulative installed capacity and offshore installed capacity of wind power will reach about 100 GW and 5 GW respectively by 2015, with the total electricity production of 190 TWh. In accordance with the approach that "constructing large bases and interconnecting into power system", it is critical for China to construct small and medium sized wind farms in inland areas endowed with abundant wind resources to promote the large-scale development of wind power. During the 12th Five-Year Plan period, 8 big wind power bases would be constructed gradually with the total installed capacity of 65 GW, namely, Hebei, west Inner Mongolia, east Inner Mongolia, Jilin, Shandong, Jiangsu, Gansu Jiuquan, Xinjiang hami [29], as shown in Fig. 7. It is estimated by NDRC that the total installed capacity of these large wind bases would be 65 GW, and the offshore wind power bases of Shandong and Jiangsu would be the crucial development districts as summarized in Table 4.

3.4. Solar photovoltaic

According to the solar radiation situation, China can be divided into five regions. In the first region, its land surface receives an annual radiant energy of 670–837 kJ/cm^2/yr with a sunshine duration of 3200–3300 h a year, including Tibet, northern Gansu, southern Xinjiang, northern Ningxia and so on. In the second region, its land surface receives an annual radiant energy of

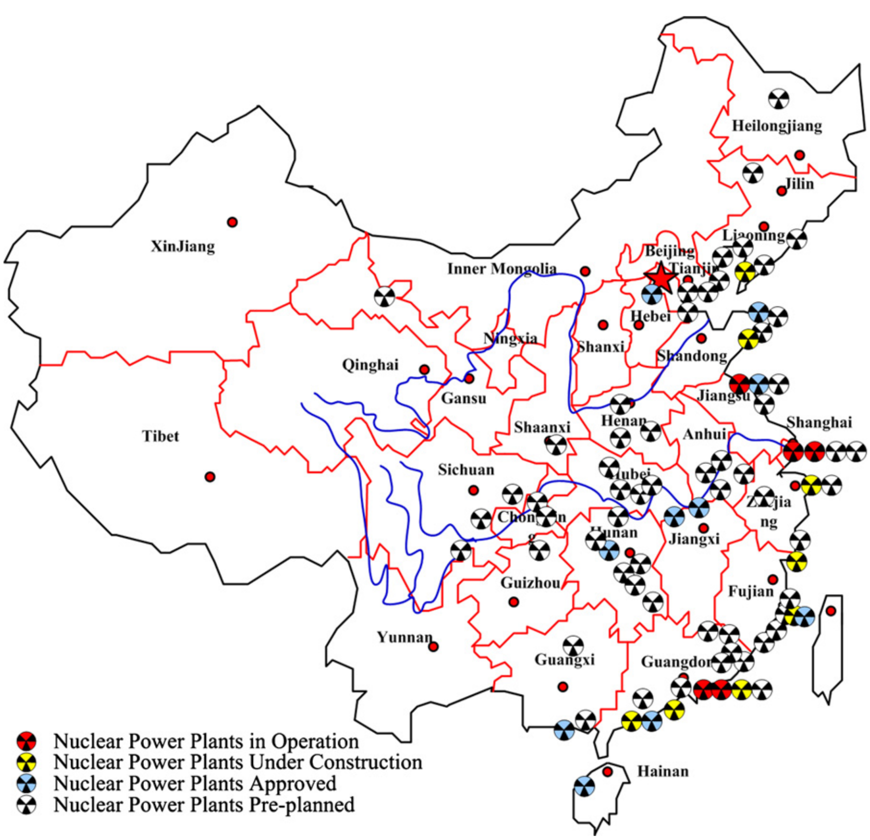

Fig. 5. Distribution of nuclear power plants in China [15,24].

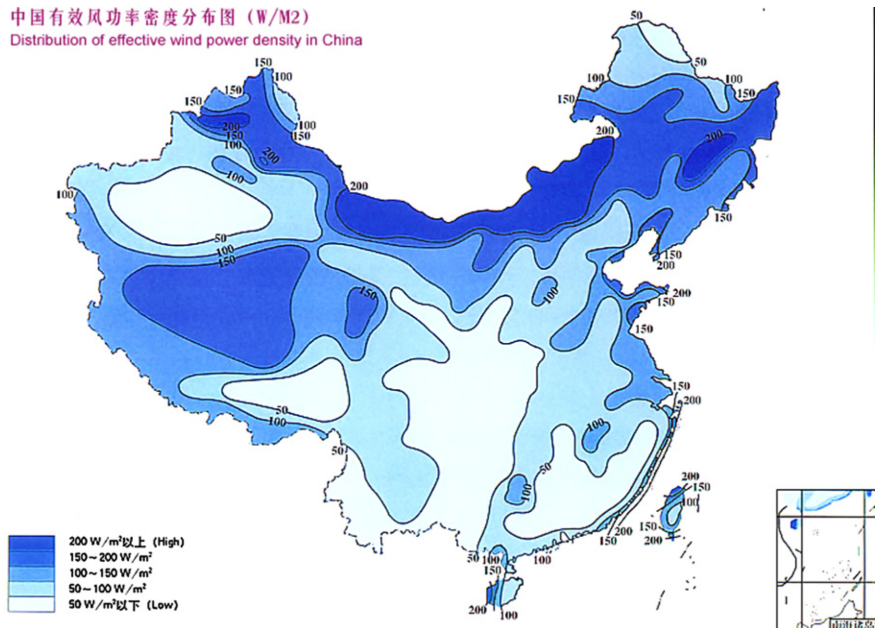

Fig. 6. Wind density map of China [29,30].

Fig. 7. Distribution of eight large wind power bases in China [29,31].

586–670 kJ/cm^2/yr with a sunshine duration of 3000–3200 h, including northwest Hebei, north Shanxi, south Inner Mongolia, south Ningxia, middle Gansu, southwest Tibet, south Xinjiang and so on. In the third region, its land surface receives an annual radiant energy of 502–586 kJ/cm^2/yr with a sunshine duration of 2200–3000 h, including Shandong, Henan, southwest Hebei, south Shanxi, north Xinjiang, Jilin, Liaoning, Yunnan, north Shaanxi, southeast Gansu, south Guangdong, south Fujian, north Jiangsu, north Anhui and so on. In the fourth region, its land surface receives an annual radiant energy of 419–502 kJ/cm^2/yr with a sunshine duration of 1400–2200 h. In the fifth region, its land surface receives an annual radiant energy of 335–419 kJ/cm^2/yr with a sunshine duration of 1000–1400 h [32]. Besides, the first, second and third regions where solar PV is of great potential cover more than two-thirds of China's land area as shown in Fig. 8.

According to the regional distribution characteristics of solar energy, China's solar bases are mainly regulated in western areas, where there is abundant solar energy and land resources. According to the 12th five-year plan, two 10 million kW photovoltaic energy bases will be built in Jiuquan and Qaidam basin. It is estimated that a quarter of Jiuquan's land is endowed with solar power of an annual radiant energy of 630 kJ/cm^2/yr [33]. In 2008, China began to build the first domestic 10 million kW wind base in Jiuquan, and the construction of wind base is accompanied with the solar base.

3.5. Other new energy resources

More than two-thirds of China's biomass resources are distributed in Inner Mongolia, Sichuan, Henan, Shandong, Anhui, Hebei, Jiangsu, and biomass generation in these regions accounts for about 70% of the total in China as shown in Fig. 9. As is stated in Report on China's New Energy development 2010, the newly installed capacity of biomass power will be 28 million kW from 2006 to 2020, and will soar to 30 million kW by 2020, accounting for about 2% of the total installed capacity [28,35].

Located in the round-Pacific and Himalaya–Mediterranean tropical zone, China is endowed with abundant geothermal resources, as shown in Fig. 10. At present, there are more than 3200 geothermal spots in China. And most high-temperature geothermal energy is distributed in north Tibet, Yunnan and west Sichuan with the potential generation of 5800 MW/30a. Besides, 2900 low-temperature geothermal systems are mainly distributed in North China Basin, Jianghan Basin, Weihe basin with natural heat release of 1.04×1014 kJ/a (equal to 3.6 million t standard coal). In the recent 5 years, the direct use of geothermal resources has been expanding rapidly. In order to change power shortage in dry season, geothermal experts proposed the approach of "coordinative dispatch of geothermal power and small hydropower". According to China Energy Research Society, the direct use of geothermal resources has reached 12604.6 GWh, with the installed capacity of 3687MWt, ranking first and third respectively in the world. According to the 12th Five-Year development Plan, the direct use of geothermal resources would scale up to 15 million t standard coal, with the installed capacity of geothermal power increasing to 0.1 million kW by the end of 2015 [25].

Table 4
Development plan of large wind bases in China [9,32].

Large wind bases	Installed capacity by 2010	Under construction	Average goal in next 10 years	Planned installed capacity by 2020
Hebei	3.58 GW	850 MW	1 GW	14.13 GW
East Inner Mongolia	3.82 GW	1.8 GW	1.7 GW	20.81 GW
West Inner Mongolia	6 GW	1.12 GW	3.2 GW	38.3 GW
Jilin	2.02 GW	260 MW	1.9 GW	21.3 GW
Jinagsu	1.28 GW	220 MW	950 MW	10.75 GW
Gansu	1.34 MW	3.8 GW	2 GW	21.91 GW
Xinjiang	4.95 MW	49.5 MW	1 GW	10.8 GW

4. Development status and barriers analysis of new energy base

4.1. Development status of new energy base

4.1.1. Hydropower

Hydropower is a clean and renewable energy. Theoretically, it is the only clean energy source that can be commercially developed on large scales at present in China. Statistics show that there are large quantities of rivers in China with hydropower potential over 10 MW [37]. According to regional distribution characteristics, the most fruitful hydropower resource is in Southwest China, including Sichuan, Yunnan, Tibet and Guizhou. And most hydropower plants in China are located in the provinces where there is a lack of coal or hydro resource is abundant, such as Liaoning, Jilin, Zhejiang, Fujian, Jiangxi, Hubei, Hunan, Guangdong, Guangxi, Chongqing, Sichuan, Yunnan, Guizhou, Shanxi, Gansu and Qinghai [24].

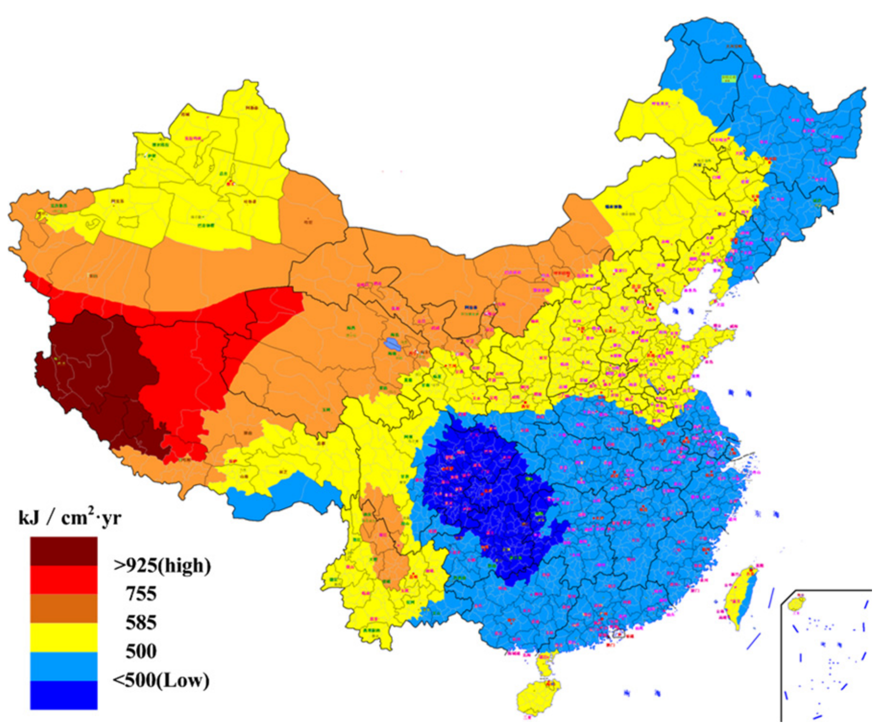

Fig. 8. Distribution of solar energy in China [33,34].

Fig. 9. Distribution of biomass resources in China [16,24].

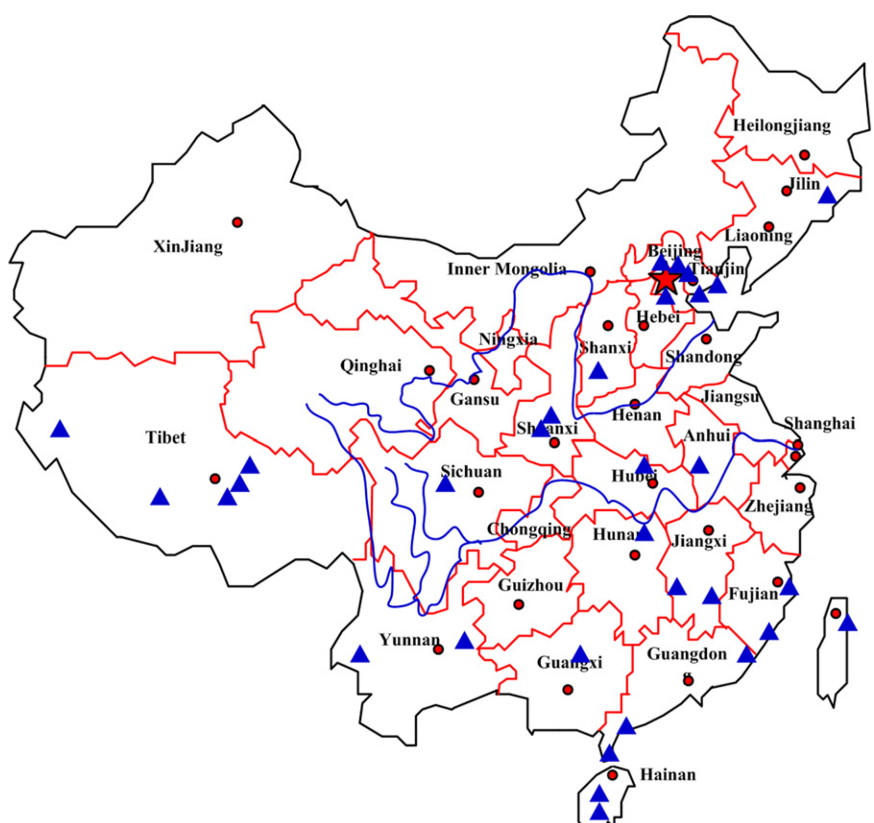

Fig. 10. Distribution of geothermal resources in China [36].

From the perspective of politics, hydropower generation is the sole and irreplaceable form of energy that transits from highly polluted fossil fuels to clean renewable energy in China, although coal-fired power will still be the dominated generation form in the foreseeable future. Since political guidelines give priority to hydropower exploitation in China, an unprecedented opportunity was brought for developing hydropower in China. By the end of 2010, the hydropower installed capacity in China reached 213.4 GW, taking up 22.2% of the total installed capacity [22]. In accordance with the distribution of hydropower resources, 13 large hydropower bases have been planned (see Table 2 and Fig. 3) by the government, and their installed capacity is expected to scale to 215 GW, accounting for 57% of the total installed capacity.

To build large-scale hydropower bases is the first choice to complete the target that non-fossil energy consumption ratio reaches 15% in 2020. By the end of 2011, China's hydropower development rate is about 43%, while the rate is generally more than 60% in developed countries. On the basis of ecological environment protection and immigrant resettlement, China will actively develop hydropower, combining hydropower development, local employment and economic development. The government should take the following measures: (1) perfect resettlement policy and improve benefit sharing mechanism, (2) strengthen the assessment of ecological environmental protection and environmental impaction, (3) strictly implement ecological protection measures of the hydropower stations that have been built and improve the comprehensive utilization level of water resources and ecological environment benefit, (4) make plans for hydropower exploitation and accelerate large-scale hydropower stations construction in key rivers Table 5.

4.1.2. Nuclear power

Since 2005, due to the support of central government, Guangdong, Zhejiang, Liaoning, Fujian, Shandong and other coastal areas are building a batch of new nuclear power stations. 7 nuclear power stations have been put into operation by the end of 2011,

Table 5
Construction of 13 hydropower bases [22,25].

Hydropower base	Total scale		Completed and under construction	
	Installed capacity (MW)	Generation (billion kW/h)	Installed capacity (MW)	Generation (billion kW/h)
Jinshajiang River	59080	274.67	0	0
Yalongjiang River	20100	115.67	3300	17
Daduhe River	17720	96.64	1300	6.63
Wujiang River	10615	33.79	2735	6.1
Yangtze River up reaches	28897	136.31	22367	103.68
Nanpanjiang River and Hongshuihe River	12012	56.39	8712	25.36
Lancangjiang River	21470	110.83	2600	12.13
Yellow River up reaches	16364.3	59.75	7719	30.02
Yellow River main	6408	19.07	1208	3.36
West Hunan	7735	31.50	3700	14.77
Fujian and Zhejiang and Jiangxi	14871	41.8	6988.5	21.23
Northeast	11983	32.11	5128.7	11.6
Nujiang River	2142			
Total	227255.3	1008.55	6575.82	251.86

Table 6
Nuclear reactors that have been built and are under construction in China (by the end of 2011) [7,38].

Process	Plant	Location	Reactor design	Unit	Rated power (million kW)	Designed lifetime (years)	Investment (billion RMB)	Constr. start
Nuclear reactors finished	Qinshan I-1	Zhejiang	CNP300	1	0.3	30	1.2	1985.3
	Qinshan II-2	Zhejiang	CNP600	2	0.65	40	14.8	1996.6
	Qinshan II-3	Zhejiang	CANDU6	2	0.73	40	2.57	1998.6
	Daya Bay	Guangdong	M310	2	0.98	40	4	1987.8
	Lingao 1	Guangdong	CPR1000	2	0.99	60	4	1997.5
	Tianwan 1	Jiangsu	AES+91	2	1.06	40	3.2	1999.1
	Lingao 2	Guangdong	CPR1000	2	0.99	60	26	2005.12
Brief summary				13	5.7			
Nuclear reactors under construction	Qinshan II-2	Zhejiang	CNP600+	2	0.65	40	14.4	2006.4
	Ningde 2	Fujian	CPR1000	4	1	60	49	2008.2
	Fuqing 1	Fujian	M310+	2	1	40	26.7	2008.11
	Yangjiang 1	Guangdong	CPR1000	6	1	60	74	2008.12
	Fangjiashan	Zhejiang	CPR1000	2	1	60	26.8	2008.12
	Sanmen1	Zhejiang	AP1000	2	1.25	60	40	2009.4
	Taishan 1	Guangdong	EPR	2	1.75	60	50	2009.12
	Haiyang 1	Shandong	AP1000	2	1.25	60	43	2009.12
	Shidao bay	Shandong	HTGR	1	0.2	40	3	
	Changjiang 1	Hainan	CNP600+	2	0.65	40	16	2010.5
	Fanchenggang	Guangxi	CPR1000	2	1	60	25.6	2010.7
Total				39	16.45		480.04	

other 15 nuclear power units are in operation and their installed capacity will scale to 12.54 million kW. The nuclear power stations which have been built and are under construction are as follows (see Table 6).

However, coastal areas were nearly full of nuclear power units before 2011. With the growing power demand, Hunan, Hubei, Jiangxi, Anhui, Sichuan, Chongqing and some other provinces will become the first places to build nuclear power stations in China. Therefore, the pattern that nuclear power stations just developed in coastal areas in past decades is breaking and the construction is towards China's inland areas.

Due to fukushima Daiichi nuclear disaster in 2011, China's nuclear power industry has experienced a stop and restart process. In March 2011, on the basis of comprehensive assessment of fukushima disaster impact, four nuclear power construction regulations were put forward which included comprehensive review on nuclear power plant under construction and suspending nuclear power projects' examination and approval. The nuclear power industry turned into "hibernation". But in October 2012, the State Council passed the 12th-five year plan of energy development. Then the council passed nuclear power development plan for the years 2011–2020, putting forward to recover nuclear power construction steadily and only arrange some nuclear power plants construction on coastal areas that have been demonstrated sufficiently [26].

In accordance with the restart and development plan, it can be seen that the development process of nuclear power on inland areas suspends and part of investment on inland nuclear power plants may fall to the ground. But from the phenomenon of the existing nuclear plants located in coastal areas, there is no doubt that nuclear power stations will be constructed in the inland areas in the future. On the other hand, new nuclear power projects must be constructed in accordance with the highest safety requirements of the state council's deployment, which improves the admittance threshold and greatly affects the safety cost of stations. Overall, China's nuclear power is still in the development and expansion process after the restart.

4.1.3. Wind power

The development scale and grid interconnection of China's wind power is fast. The accumulative installed capacity of China's wind power is 62.7 GW, and that of integration wind power is 47000 MW by the end of 2011 [14]. However, the regional gap of wind power installed capacity is large in China. For example, Inner Mongolia developed faster than other provinces; its newly added installed capacity and accumulated installed capacity were 3736.4 MW and 17594.4 MW respectively in 2011, which account for 21.2% and 28.2% respectively of the total national level. In addition, the total capacity in HeBei, GanSu, LiaoNing and ShanDong provinces is over 4 GW for all. Among them, ShanXi province is the fastest one in capacity growth with the rate of 96.8%, while the growth rates of QingHai, GuiZhou, ShanXi, NingXia, TianJin and YunNan province are 83.7%, 78.5%, 64.4%, 59.0%, 57.9% and 53.8% respectively [19]. At present, as Inner Mongolia, GanSu, XinJiang, HeBei, JiLin and JiangSu provinces are endowed with rich wind energy resources, the planning and construction of seven 10-million-kilowatt-level wind-power bases will be carried out there.

The wind power development in China comes into a stable stage after several years' rapid expansion. In 2011, the traditional "three norths" areas relying on advantageous resources superiority and local policy support are still keeping lead on wind power development. Meanwhile, central and eastern regions further act as emerging markets, and the development speed of distributed wind power cannot be ignored. Therefore, a new situation that emerging and old markets keeping pace with each other is forming. At the same time, the integration and digestion of wind power has become a major challenge which restricts the sustained development of wind power in China.

During the 12th-five year plan, centralized exploitation and disperse development will act together to optimize the layout of wind. Main measures are as follows: (1) the government should in an orderly way promote wind power construction in northwest, north and northeast China where wind energy resources are rich and speed up the utilization of disperse wind energy resources, (2) the government should perfect wind power equipment standards and industry monitoring system, (3) wind power equipment enterprises should be encouraged to strengthen research on key technologies, which will speed up the wind power industry technology upgrade, (4) power grid's dispatching level and equipment performance should be improved, (5) the government should improve the ability of wind power consumption [21].

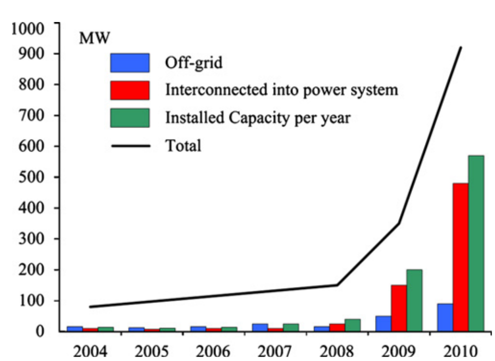

Fig. 11. Installed capacity of solar PV from 2004 to 2010 in China [7,34].

4.1.4. Solar photovoltaic

China's large-capacity solar PV bases were in the phase of interconnecting to the power system, with total installed capacity of 256,200 kW and newly installed capacity that interconnected to the power system of only 194,900 kW in 2010, as shown in Fig. 11. However, when large-capacity solar PV power station came into operation stage, the total installed capacity reached 3 million KW and newly installed capacity was about 2.2 million KW in 2011. By the end of 2011, the cumulative in-building or proposed projects were more than 9 GW and formal completed construction projects reached 2.7 GW Table 7.

According to the photovoltaic power generation development plan, the development advantages of solar energy resources, hydropower, wind power and other new energy in Xinjiang province will be combined by making good use of resources in Xinjiang province to speed up energy resources transformation. Meanwhile, it is of great significance to promote the construction of large-scale solar energy base connected to the grid in the southern and eastern regions in Xinjiang and strongly support large-scale grid-connected solar power plants to be built in Inner Mongolia, Shanxi, Ningxia, Yunnan, and Tibet during the 12th five-year plan period [39], as summarized in Table 8.

Desert regions are good places for the development and utilization of large-scale photovoltaic power generation as power supply has the character of discontinuity and instability. Therefore, the construction of PV bases is likely to combine with hydropower in the future. Large desert areas in China are mainly distributed in Xinjiang, Inner Mongolia, Gansu and Qinghai province, where total desert areas are 0.71 million km^2. It means that 130 billion kW power can be sent out every year. Among them, Xinjiang province is a key construction base. The installed capacity of photovoltaic power stations in Xinjiang desert areas were 470,000 kW by the end of 2011. In order to improve desert solar energy conversion

Table 7
Installed wind power capacity of different provinces in China by 2011 [13,17].

Province	Cumulatively installed capacity (MW)	Newly installed capacity (10 MW)	Province	Cumulatively installed capacity (10 MW)	Newly installed capacity (10 MW)
Total	62364.2	17630.9	Henan	300.0	179.0
Beijing	152.5	2.5	Hubei	100.4	30.7
Tianjin	243.5	141.0	Hunan	185.3	88.0
Hebei	6969.5	2175.5	Guangdong	1302.4	413.6
Shaanxi	497.5	320.5	Guangxi	79.0	76.5
Inner Mongolia	17594.4	3736.4	Hainan	256.7	–
Liaoning	5249.3	320.5	Chongqing	46.8	–
Jilin	2940.9	622.5	Sichuan	16.0	16.0
Heilongjiang	3445.8	1075.8	Guizhou	195.1	153.1
Shanghai	318.0	48.6	Yunnan	932.3	501.8
Jiangsu	1967.6	372.3	Hongkong	0.8	–
Zhejiang	367.2	69.0	Shanxi	1881.1	933.6
Anhui	297.0	148.5	Gansu	5409.2	465.2
Fujian	1025.7	192.0	Qinghai	67.5	56.5
Jiangxi	133.5	49.5	Ningxia	2886.2	1703.5
Shandong	4562.3	1924.5	Xinjiang	2316.1	952.5

Table 8
Large-scale solar power plants planned in 2010 [15,40].

Location	Installed capacity (MW)
Qinghai Henan	30
Gansu Baiyin	20
Gansu Jinchang	20
Gansu Wuwei	20
Shanxi Yulin	20
Inner Mongolia Alashan	20
Inner Mongolia Baotou	20
Inner Mongolia Bayannaoer	20
Xinjiang Hami	20
Xinjiang Turpan	20
Xinjiang Hetian	20
Ningxia Qingtongxia	30

and utilization, the government plans to increase photovoltaic generation capacity to 1.5 million kW before 2015, accounting for three quarters of total photovoltaic power installed capacity in Xinjiang. Finally, Xinjiang will be built as China's biggest "optical valley" and largest photovoltaic industry demonstration base in the west. Solar radiation received by desert every year is equivalent to 400 billion t standard coal, so it is suitable for building large desert photovoltaic power stations [33].

4.1.5. Other new energy resources

According to the data issued by the State Electricity Regulatory Commission, the installed capacity of biomass power was 4.36 million kW in 2011, accounting for 0.41% of the total installed capacity. Biomass power generation was 19.12 billion kWh, which accounted for 0.40% of the total generation in 2011 [40]. Government will strengthen the support degree of biomass, and the proposed construction projects will be put into production in succession. It is expected that biomass energy generation scale will reach 8.5 million kW in 2012. In addition, biomass power generation projects are growing rapidly. At present, 106 projects have entered into approval procedures, whose total generation may be more than 3000 MW and average investment is 11,000 Yuan/kW [9]. The number of power generation projects is more than 30, and most of the other projects have stopped after project approval. However, biomass power generation projects which are already in production face adverse conditions, for example, scattered resources and high cost of collecting raw material restrict the development of biomass energy seriously.

The development of biomass energy is relatively slow in China and its fundamental reason is straw collection, which leads to hundreds of millions of tons of straw getting burned in vain every year. Therefore, there is a wide space to develop biomass power generation project in rural areas where crops are abundant. At present, many enterprises in China collect abandoned branches from orchards directly and then burn for biomass energy. This is not only enabling the use of green energy, but also promoting local economic development. However, by only using agricultural straw and other raw materials, China's total available scale of biomass energy is 500 million t standard coal. The generation cost of biomass power is lower than cost in photovoltaic industry. Biomass energy, as a new energy field, includes straw, algae, methane, trees, livestock feces, etc. These energy resources distribute widely and have great exploitation potential. Besides, biomass energy only has a small impact on environment and can be used sustainably.

4.2. Barrier analysis of new energy base

4.2.1. Policy problems

(1) New energy development policies in China
The new energy industry is a typical policy-oriented industry [18]. In order to maintain the fast and stable economic growth without severe environmental degradation, it is of great importance to promote new energy development [19]. China's government has stipulated several incentive policies for new energy development and consumption. Those concerning hydropower, wind power, solar power, nuclear power and other new energy resources are summarized in Table 9.

(2) Policy issues
1) Overall plan for new energy bases construction is absent in China
There is no overall plan for new energy bases construction, resulting in low investment efficiency. An overall plan for new energy bases construction in China is still absent when new energy is highly developed. The related department has been focusing on new energy integration while making grid construction to relatively lag behind. The two main problems are (1) that generation planning is not coordinated with the grid planning and (2) blind investment is existing in many places. Take wind power as an example. Most of the million kilowatt wind power bases are constructed without supporting sending-out grid, which leads

Table 9
New energy development policies in China [1,4,7,41–44].

Type	Promulgation time	Departments	Laws and regulations	Briefs
New energy bases	2010	People's Government of Guangzhou	Energy-saving and new energy industry development planning in Guangzhou	Bring out the prior developing industries: smart grid, energy-saving building, new efficient battery, solar cell, wind power equipment, and energy service
	2011	Bureau of Energy	National energy meeting: rationally control total energy consumption during the 12th five-year-plan period	Rationally control the total energy consumption; adjust the power structure; bring out international cooperation concerning energy; focus on the consumption of five big energy bases; promote the reform in ways of energy production and utilization; establish a secure, stable, economic and clean energy industrial system
	2011	NDRC	Planning of regional division based on function	Construct big wind power bases in Hami, Dabancheng, etc. and solar power bases in Hami, etc. Build quantities of million kilowatt wind farms in Inner Mongolia; promote the construction of hydropower bases in Jinshajiang, Daduhe, etc. Build nuclear bases in east coastal regions
	2011	People's Government of Zhejiang province	Strategic planning for building new energy bases in Xinyu	Build a national new energy base and a global photovoltaic power bases
	2011	The State Council	Certain opinions on further promoting economic development in Gansu from the general office of the state council	Build wind power bases centered in Jiuquan and Jiayuguan and solar power bases centered in Dunhuang, and work for 10 million kW wind power bases and million kilowatt solar power bases; actively explore local power subsidy policies; realize complementary among wind power, solar power and nuclear power
	2012	Bureau of Energy	12th five-year plan for renewable energy	Bring out the global renewable energy development goal and targets of each kind of renewable energy
	2012	The State Council	12th five-year plan for energy development	During the 12th five-year-plan period, we should speed up reforms on ways of energy production and utilization, globally improve the conversion efficiency and utilization efficiency, rationally control the total energy consumption and establish a safe, stable, economic and clean energy industrial system
Hydropower	2007	NDRC	Mid- and long-term development programming for renewable energy	Set up special fund for developing new energy in support of the technical research and industrial construction of renewable energy
	2008	NDRC	11th five-year plan for renewable energy	Accelerate the construction of hydropower bases and small hydropower bases
	2008	SERC	Notification on subsidies for renewable energy tariff and quota trading program	Set up capital fund stimulating new energy interconnecting into power systems
	2010	Ministry of Finance and Ministry of Construction	Notice on the application and demonstration of renewable energy building	Promote the use of solar energy, shallow geothermal energy and other forms of renewable energy in the construction field
	2011	Bureau of Energy	Notice on further construction of pumped storage power station	Focus on the site and construction plan of pumped storage power station
	2011	Bureau of Energy	Notice on strengthening the management of hydropower construction	Strengthen the pre-design and construction quality control of hydropower projects
	2011	MWR	Policies regarding water resource in nuclear project and the construction of technology system	Regulate the water resource management in nuclear project
Nuclear power	2007	NDRC	Mid- and long-term development programming for renewable energy	Adjust the development policy of nuclear power from "moderate" to "positive", and then to "massive"
	2007	NDRC	State mid- and long-term development programming for nuclear power	Arrange the layout and schedule of nuclear power construction project; study resource development and reserve site
	2007	SERC	Regulatory measures for grid enterprises' acquisition of new energy	New energy unit should be integrated into the grid on the basis of meeting the relative integration technology standard; the electricity regulatory intuition should supervise the power generation, grid operation and integration
	2008	Ministry of Finance	Notice on the related tax policy issues of nuclear power industry	Implement "front-end back" policy of added value tax in nuclear power sale enterprise; tax refund is exempt from corporate income tax
	2011	People's Government of Zhejiang province	Development plan of nuclear power related industry in Zhejiang province	Up to 2015, nuclear power service bases and nuclear power plant manufacturing bases are built
	2012	The State Council	Mid- and long-term development programming for nuclear power	Stably recover nuclear construction; scientifically dispatch the nuclear projects and increase the standard; by 2020, the installed nuclear power capacity in China will reach 58 million kW, with another 30 kW under construction
Wind power	2007	NDRC	Mid- and long-term development programming for renewable energy	Construct large-scale wind power projects, wind power bases and offshore wind power pilot projects

	2008	Ministry of Finance	Notice on the adjustment of import tax policy of high-power wind turbine, its key components and raw materials	Implement ''front-end back'' policy of added value tax and import tariff for imported great power fan, key components and raw materials
	2008	NDRC	11th five-year plan for renewable energy	Construct million kilowatt wind power bases in Inner Mongolia, Jiangsu, and Hebei; construct 2100 thousand kilowatt offshore wind power pilot projects
	2011	NDRC	Interim measures of the development and construction of offshore wind power	Strengthen project approval, project construction and operation management of offshore wind power projects.
	2011	SERC	Notice on strengthening safety supervision and management of wind farms to curb large-scale wind turbine off-grid	Ensure wind farm operation satisfying technical requirements of interconnecting into power system
	2011	NDRC and Ministry of Finance	Implementation views to promote wind power industry development	Support the industrialization of wind power equipment
	2012	Bureau of energy	12th five-year plan for wind power development	Develop wind power on a large scale and increase the ratio of wind power in all power resources; speed up technology research on wind power
Solar power	2007	NDRC	Mid- and long-term development programming for renewable energy	Construct the roof solar PV power pilot sitting in Beijing, Shanghai, Jiangsu, and Shandong during 12th five-year plan period
	2008	NDRC and State Council	11th five-year plan for renewable energy	Construct large-scale solar PV pilot programs in Gansu, Dunhuang, and Tibet; construct solar thermal power generation demonstration projects in Xinjiang
	2009	Ministry of Finance	Interim measures of solar PV building applications for financial assistance fund management	Promote and extend solar PV building techniques used in general rural areas; provide financial subsidies to photovoltaic power generation projects
	2011	NDRC	Notice on optimizing photovoltaic power price policies	Set a unified on-grid electricity price for photovoltaic power and determine the price of photovoltaic power that has received financial subsidy
	2012	Bureau of Energy	12th five-year plan for solar power industry	Set the goal for solar power industry; determine the layout of solar power and key works
	2012	MIIT	12th five-year plan for photovoltaic power industry	Set the cost goal for photovoltaic power and promote its development
Other new energy	2007	NDRC	Mid- and long-term development programming for renewable energy	Focus on biomass power, biogas, bio-solid fuel, and bio-liquid fuel; support agricultural biomass power, forestry biomass power, biogas power and waste generation
	2007	The NPC Standing Committee	Law of Conservation of Energy	Encourage the rural development and utilization of biogas, geothermal and other renewable energies
	2009	Ministry of Finance	Notice on energy conservation and new energy vehicle demonstration pilot work	Study and formulate the policy for the development of new energy vehicles; support technical advances in new energy vehicles; provide favorable taxation policy for new energy vehicles
	2010	NDRC and Ministry of Industry	China Policy of Resource Comprehensive Utilization	Provide favorable taxation policy for new energy power, e.g., exempt from tax and ''front-end back'' policy

to wastage of wind resource and an efficiency decrease. The wind power utilization time in China on average was only 1920 h in 2011, indicating that wind power abandonment was quite common in China. Besides, the radical investment of wind power by now has left no room for more advanced technology [45]. When it comes to hydropower, radical investment that ignores the coordination of hydropower plan with water resource plan and ecological protection could also be found. Many nuclear bases are also being constructed before supporting systems such as nuclear waste disposing and personnel training are completed.

2) The new energy policy mechanism is deficient
The new energy policy system is deficient, leaving new energy bases construction without sufficient and reliable guarantee. A series of new energy supporting policies are issued in China, which are mostly general provisions. Therefore, tariff policy, tax subsidy policy and other supporting policies for new energy are far from perfect. Specifically, (1) fixed benchmarking on-grid electricity price is used for wind power generation and PV power generation, which lacks flexibility and is not efficient in encouraging grid enterprises to purchase new energy power and making inter-regional power exchange [34]. (2) The electricity price subsidy mechanism is not sound. At present, renewable energy power price surcharge is the main source for new energy price subsidy, while fossil fuel tax is not included. The settlement mechanism also has defects [46]. The wind power price subsidy is settled every half a year, which is lagging behind in time and then may bring financial risks to wind farms. (3) The auxiliary service compensation mechanism in China is not sufficient enough, thus power plants are not active in peak regulation. (4) Coordinative development policies for new resource, society and ecological environment are not all in place. In particular, perfect supporting policies concerning migration settlements, land utilization and ecological protection are needed for hydropower and biomass development.

3) New energy management system and market mechanism are not sound.

The current management system and market mechanism are not adapted to massive new energy utilization. The energy management system based on conventional energy is not fit for new energy; and power system operation and management mechanism are focusing on the characteristics of large-scale power resources and big grid, taking little consideration of new energy. Specifically, (1) the electricity trading mechanism in China, especially the inter-province trading mechanism, is not sound, which hinders new energy power consumption to a large extent. Besides, difficulties in price negotiation and transmission losses compensation also limit the utilization level of new energy. (2) Integration and grid-connected operation mechanism adaptive for new energy integration are not complete in China, restricting its further development [45,47]. The larger the scale of new energy power is, the bigger the challenges will be. It is indicated that electricity management system and market mechanism are in urgent need.

4.2.2. Technology barriers

(1) Development cost is high
New energy development cost is too high. Technology and economics are the two basic problems for new energy bases development. Recently, great progress has been made in new energy technology, as well as the economics of new energy development. However, despite great achievements, most new energy industries are still in their primary stage except for hydropower and solar water heater, suggesting that development and utilization costs are high, which contribute to the low competitiveness of new energy in the current market, together with the problems of uneven new energy resource distribution, small market scale and inability of continuous generation [48]. Hence, new energy is now highly relied on the supporting policies to compete with conventional energy. Take biomass as an example. The main reason why biomass power generation could not developed in large scale as wind and solar energy is that agriculture production is highly decentralized in China. Biomass resource is in such a highly scattered state that straws are possessed by individual peasant, inevitably increasing the acquisition cost and transportation cost.

(2) New energy technologies in China are far from advanced
At present, technology and innovation system with core competitiveness are lacking in China; key technologies are still lagging far behind those of advanced countries. There is no systematic new energy technology development mechanism, indicating that technology innovation ability is not as strong and research on core technology and generic technology is as well still uncompleted. All these contribute to low competitiveness and low economics. In solar-thermal power generation, for example, groove thermal power generation technology is the most mature one, of which the vacuumed collecting-heat tube is of high damage rate. Besides, the conduction oil used is extraordinarily expensive, usually above 30,000 RMB a ton. Actually, groove thermal power generation technology is mature but not desirable. As for other technologies, solar tower power generation technology is still of low generation efficiency and solar butterfly generation technology is under test. Moreover, solar–thermal power plants are better located in Gobi areas abundant in solar thermal resource, water resource and land resource, such as Inner Mongolia. However, there is always sandstorm in Inner Mongolia, which makes taking care of heliostat drive shaft and preventing reflection efficiency decline at the same time difficult [49].

(3) Traditional power grid restricts new energy development.
Traditional power grid is usually not compatible with intermittent power resource and is of high transmission losses, highly restricting new energy development. With the rapid development of new energy power industry, solar power and wind power integration has become a main difficulty. At present, it is a fact that power storage technology is imperfect, grid integration technology is immature and the intermittency problem of solar power and wind power remains unsolved. Thus, the existing grid could not receive and then consume massive new energy power. Besides, the fluctuation of wind power and solar power, as well as their poor adjustability, increases power grid uncontrollability and also puts more pressure on peak regulation, which brings unstable strike to the grid. Therefore, smart grid construction is the key to integration problem. However, smart grid construction could hardly catch up with the rapid development of new energy in China by far. As a result, more challenges concerning grid-integration and power consumption will emerge and limit new energy development.

5. Recommendations

5.1. Policy recommendations

(1) A systematic plan should be carried out in a global perspective
A systematic plan for new energy bases construction and development should be put forward on the basis of target analysis, taking energy resource, market conditions, environmental effects into consideration [50]. (1) The related authority

should coordinate generation planning with the planning of grid and supporting facilities, thus promoting new energy power consumption and improving the economic operating efficiency of new energy bases. (2) In regions where sharp conflict between new energy power generation and consumption exists, pertinent and feasible measures are needed. The present integration state should be considered as one of the main indicators for new energy planning, for example, regions with excessively low wind power utilization time are not allowed to expand the scale of new energy bases. (3) The government and enterprises should thoroughly consider the effects that new energy bases construction has exerted on environment, coordinate the relationship between new energy development and ecological protection, and prevent environment damage and pollution, thus making long run benefits.

(2) The new energy supporting policies should be optimized
The new energy supporting policies should be optimized, especially sound tariff and price subsidy mechanism. The related authority should make full use of the market mechanism effect in allocating resources and go further on consummating the supporting policy mechanism. Energy tariff and tax mechanisms that could reflect resource scarcity and external environmental cost should be carried out on the basis of fitting the principle of economic and reasonable dispatch and benefiting new energy bases development. National standard for new energy products subsidy should be established. In detail, (1) the new energy on-grid electricity price policies should be adjusted to increase its flexibility [4]. (2) The related department should improve new energy base development fund management and rationally dispatch the money. (3) The government should adjust power price subsidy mechanism and take measures concerning capital resource, settlement, distribution procedure and time efficiency to improve subsidy mechanism efficiency. (4) The related department should make detailed and feasible compensation scheme for auxiliary service. (5) The government should put forward global supporting policies regarding migration settlement, land utilization and ecological protection for hydropower and biomass power.

(3) The related department should explore new promotion mechanism for new-energy base
The related department should continue promoting power system reform and electricity price reform and establish new kind of power system operating mechanism that satisfies new energy integration, price mechanism and coordination mechanism that promotes local micro-grid application. (1) The related department should build a regional smart power operation management system concentrating on new energy generation in local power system where new energy power takes great ratio, so as to ensure the full use of new energy power and make safe grid operation [7]. (2) There should be important rules in power operation management that wind power takes the priority to integrate into the grid and accelerate smart grid construction (details in Section 5.2). (3) The government should better implement the renewable portfolio mechanism, thus setting its responsibility to use new energy power. (4) The related department should improve the new energy power trading mechanism, the inter-province power trading mode, price mechanism and settlement mechanism in particular, so as to promote the inter-province consumption of new energy power.

5.2. Technology recommendations

(1) The related department should accelerate smart grid construction
Controllable power plants of appropriate scale should be built to improve the peak regulation ability of the grid. It is important to make full use of surrounding coal resource, hydropower resource and solar energy to realize the complementarity of traditional controllable power resource and intermittent new resource. The related department should take supporting grid project as one of the preliminary works of new energy base construction, so as to coordinate grid planning and generation planning [5].
The State Grid has put forward the strategic target on developing smart grid in accordance with the characteristic of energy resource and the economic situation in China [21]. During the 12th five-year-plan period, the State Grid will focus on the construction of main power network that connects the wind power bases, hydropower bases, nuclear power bases, photovoltaic power bases and main load centers on the basis of optimizing power structure and power plants layout, thereby optimizing resource allocation on a larger scale, establishing an adjustable electricity trading platform, reducing the waste of hydropower and wind power, and consequently reducing the consumption of fossil energy power [2]. The State Grid determines that after three stages of innovative development, the strong smart grid that takes extra-high voltage synchronous power network as its center will be built by 2020; the smart grid is able to optimize resource allocation on a larger scale with higher efficiency, which is more secure, more reliable and has more interactivity. It has important significance on recovering cost and encouraging new energy investment to realize clean power transmission through smart grid. The smart grid construction plan of China during the 12th five-year-plan period is shown in Fig. 12.

(2) A global technology innovation mechanism should be established
A global technology innovation mechanism that includes the participation of the government and enterprises should be built, aiming at technology with independent intellectual right. National new energy technology R&D platforms should be built on the basis of existing research team [1]. The local government should also establish new energy technology innovation base, consequently forming a joint platform including the State, the local government and the enterprises. The related department should encourage universities and research institutes to engage in new energy research to promote its development. A long run research mechanism with continuous investment and supporting plans is also needed.
Specifically, several measures designed for new energy technology and construction and development cost should be taken. (1) For solar power base, measures should be taken to make solar thermal power complementary with photovoltaic power, greatly reducing cost and increasing competitiveness in price. (2) The wind farms could reduce wind power facilities cost so as to largely reduce wind power base construction cost [4]. (3) Promoting the research on home-bred wind turbine and the cooperation among wind power equipment enterprises are also key measures. The joint research and development of enterprises may significantly reduce risks. In addition, much more intensive measures should be taken by the government to encourage private capital to be put in new energy industry.

6. Conclusion

Big energy bases construction is an efficient way to promote the utilization and development of renewable energy. During the 12th Five-Year Plan and 13th Five-Year Plan period in China, new energy such as hydropower, nuclear power, wind power and solar

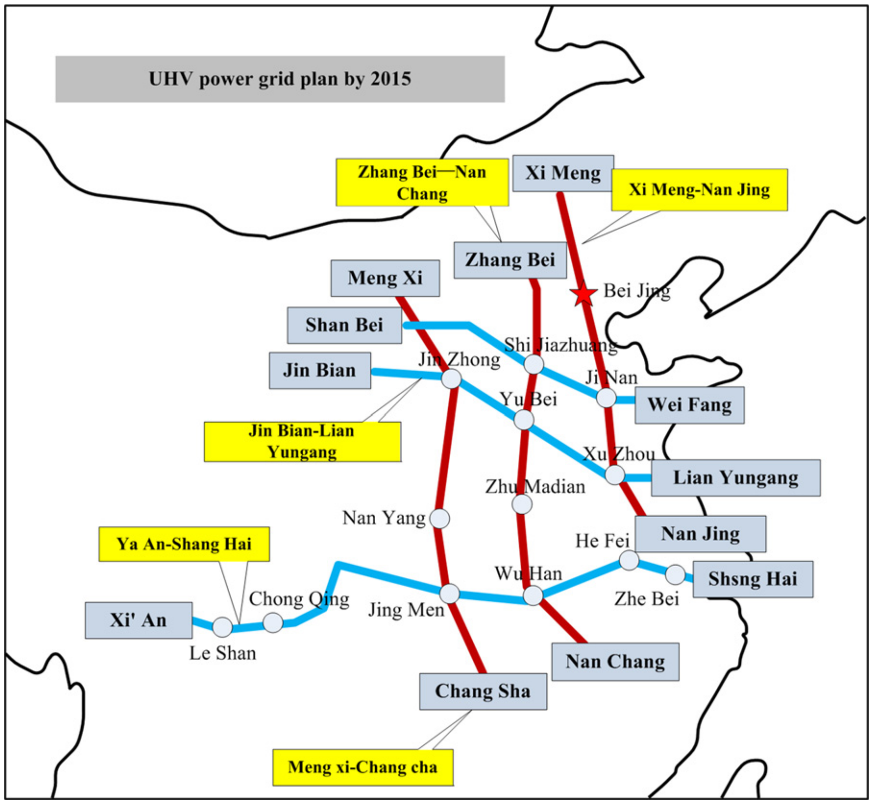

Fig. 12. UHV power grid plan by 2015 [21].

power will be greatly encouraged. As for hydropower, 13 big hydropower bases will be constructed during the 12th Five-Year Plan and 13th Five-Year Plan period, while the hydropower bases in Tibet will be mainly developed after 2030. In terms of nuclear power, the related department will focus on the later expansion of nuclear projects under construction located in coastal zone, and nuclear power bases will also be built in eastern areas. In accordance with natural resource endowments, 2 million kW photovoltaic power bases in northwest inland regions and 13 wind power bases in northeast, north, northwest, southeast coastal areas would be constructed. Constricted by resources and investment costs, it is difficult for China to realize the large-scale development of biomass power and geothermal energy during the 12th five-year plan and 13th five-year plan period. However, their market share will increase gradually. From the comprehensive perspective, thermal power and hydropower will dominate the power system for a very long period in the future. Government support is the key and initial power for renewable energy development. Supported by government policies, a more healthy and rational power system will be formed with the wide application of new energy resources. Therefore, in order to effectively encourage and promote new energy technology development, state and local governments should stipulate some principles and introduce more explicit economic incentives to promote the application of new energy technologies and achieve energy reduction targets.

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